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**EDGERTON, GERMESHAUSEN & GRIER, INC.**

# PRE-BANSHEE CALIBRATION DETONATION



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Clyde B. Dobbie

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Edgerton, Germeshausen & Grier, Inc.

Boston, Massachusetts

EG&G Report No. B-2687

CONTRACT NO. DA49-146-XZ-092

This work was accomplished under
NWER Subtask 01.001 for the
Defense Atomic Support Agency
Washington 25, D. C.



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## ABSTRACT

Electromagnetic measuring equipment was installed at Aberdeen Proving Grounds, Maryland, and operated during the sea level detonation of a spherical 500 pound Pentolite charge. The purpose of this project was to check the operational readiness of the equipment to be used during the BANSHEE test series, to obtain some indication of its EM detecting capabilities, and additionally to obtain a crude measure of the EM signal generated by such a detonation for use in future calibrations.

Each set of equipment used consisted of three mutually orthogonal loop antennae, low level amplifiers and matching networks, a 4-channel tape recorder, and a Fiducial generator Type TD-2A.

A signal was detected on only one antenna which was located 1, 000 feet from the detonation. There are uncertainties regarding the source and character of the detected signal which have not been resolved.

## ACKNOWLEDGEMENT

The authors wish to acknowledge the efforts of James R. Mazurek, their associate at EG&G, Inc., in contributing to this project. Mr. Mazurek was responsible for the assembling of the equipment in Boston, for seeing to its safe arrival at Aberdeen Proving Grounds, Maryland, and for the installation and initial checkout of the equipment when it arrived.

Additionally, Mr. Mazurek performed some of the initial data analysis.

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# CHAPTER 1

# INTRODUCTION

The purpose of making electromagnetic (EM) measurements during the Banshee series was to determine if a significant amount of EM energy is generated by the expulsion of the earth's magnetic field as a result of the expansion of the detonation wave front within, and the expansion of the shock front in the atmosphere outside of an explosive charge. The measurements would test the Magnetic Bubble Theory of EM Generation proposed by Dr. R. C. O'Rourke of EG&G.

Prior to EG&G's participation in Phase II of the Banshee HE test series at White Sands Missile Range (WSMR), the equipment to be used was installed at the Aberdeen Proving Grounds and operated during the detonation of a 500 pound spherical charge of pentolite. The purpose of this Pre-Banshee Calibration detonation was to check the operational readiness of the EM monitoring system to be used during Project Banshee and to obtain a crude measure of the EM signal generated by a high explosive (HE) detonation at sea level. These close-in EM measurements would then be used as a basis for predicting signal strengths and determining the sensitivity settings of the monitoring equipment to be used during the Banshee tests.

The EM detecting and recording equipment was that which was designed and constructed for the proposed "Lollipop" nuclear event which was to take place at some later date. There were two identical systems each consisting of a set of three mutually orthogonal loop antennas, low level amplifiers and matching networks, and a 4-channel tape recorder. A detailed description of this system is given in Appendix A of this report.

A fiducial pulse, used for time correlation between photographic and EM data, was supplied by an EG&G type TD-2A Fiducial Marker, which is described in Appendix B.

## CHAPTER 2

## PROCEDURE

Antennae sets were located approximately 1,000 feet and 1350 feet from the point of detonation. Each antenna set was oriented with one loop horizontal, one loop vertical and normal to the line of sight between it and the charge, and the third loop with its plane coincident with the vertical plane containing the charge and the antenna set. The two antennas were on a magnetic bearing of approximately $290^{\circ}$ from the charge.

The EM recording equipment was housed in Building 1196 on Spesutic Island at a distance of approximately 1200 feet from the 500 pound HE charge. Each antenna section relayed the received signals to the Recording Rack. The signals were amplified at the antennas and at the Recording Rack prior to being recorded on magnetic tape. The Recording Rack also contained provisions for a manual check out of the entire system (see Appendix A).

In addition to the foregoing, the TD-2A detected the flash of the detonation to be used as a correlation between the photographic and EM data. The output from the TD-2A was a time signal fiducial pulse which was applied to the timing channel of each tape recorder (see Appendix B).

### CALIBRATION

The system was calibrated by the shield injection method. A current was driven through the electrostatic shield of each antenna to produce a known total flux of a known frequency at the antenna coil.

This magnetic flux, $\phi(t)$, as a function of time, was of the form

$$\phi(t) = \Phi_o \sin(400 \times 2\pi t) \qquad \text{oersteds} \tag{1}$$

where

$\Phi_o$ is the peak magnitude of the magnetic flux

The output from the antenna is proportional to the rate of change of flux. This is shown by

$$e_{out} = -K_1 \frac{d\phi}{dt}$$

$$= -K_1 \Phi_o \, 800\pi \cos 800\pi t \tag{2}$$

where

$e_{out}$ is the voltage out of the terminals of the sensing loop

$\frac{d\phi}{dt}$ is the rate of change of flux with respect to time in oersteds/sec

and

$K_1$ is the scale factor

A signal proportional to $e_{out}$ was recorded on one track of the tape recorder.

Data retrieval was accomplished by recording on a visicorder, the playback of the output from the tape recorder. By also recording a calibration signal on the same visicorder track, a scale factor relating gauss per second per deflection (in inches) was derived. This scalar factor assumed the existance of a uniform magnetic flux density surrounding the receiving antenna.

In addition to amplitude calibration, a polarity calibration was used. A positive deflection on the visicorder trace was made to correspond to an increasing magnetic flux in the vertical (up) direction on the one channel which recorded significant data.

## MEASURED DATA

The curve in Figure 1 is a plot of the recorded $\frac{dH}{dt}$ signal with the appropriate scale factor applied. The plot represents the output from the nearest horizontal antenna which detected the only significant data during this test. This output signal is the local time rate of change of magnetic field at the pickup antenna.

The curve in Figure 1 has been integrated to produce the curve in Figure 2, since the magnitude of the magnetic field is more amenable to interpretation than the $\frac{dH}{dt}$ plot. Figure 2 is now a plot of the absolute values of the magnetic flux density caused by the source transmitter in the vicinity of the receiving antenna.

It is customary to specify field strength in terms of the electric field rather than the magnetic field. At distances greater than one-sixth of a wavelength from the transmitting antenna, the electric and magnetic fields are related by a constant

$$\mathcal{E} = 3 \times 10^4 H$$

where

$\mathcal{E}$ is the electric field measured in volts per meter

and

H is the magnetic field measured in gauss

During this particular test, the shortest wavelength to which the system was sensitive was approximately 50, 000 feet (20 kc). Since our antenna was located about 1, 000 feet from the point of detonation, it is obviously less than one-sixth wavelength from the source and was not in the radiation zone. The relationship between the electric and magnetic fields is therefore, considerably more complex than that indicated by the expression above. This mode of energy transfer corresponds very closely to simple magnetically coupled circuits so the data has been presented in terms of magnetic field strengths which was the quantity actually measured.

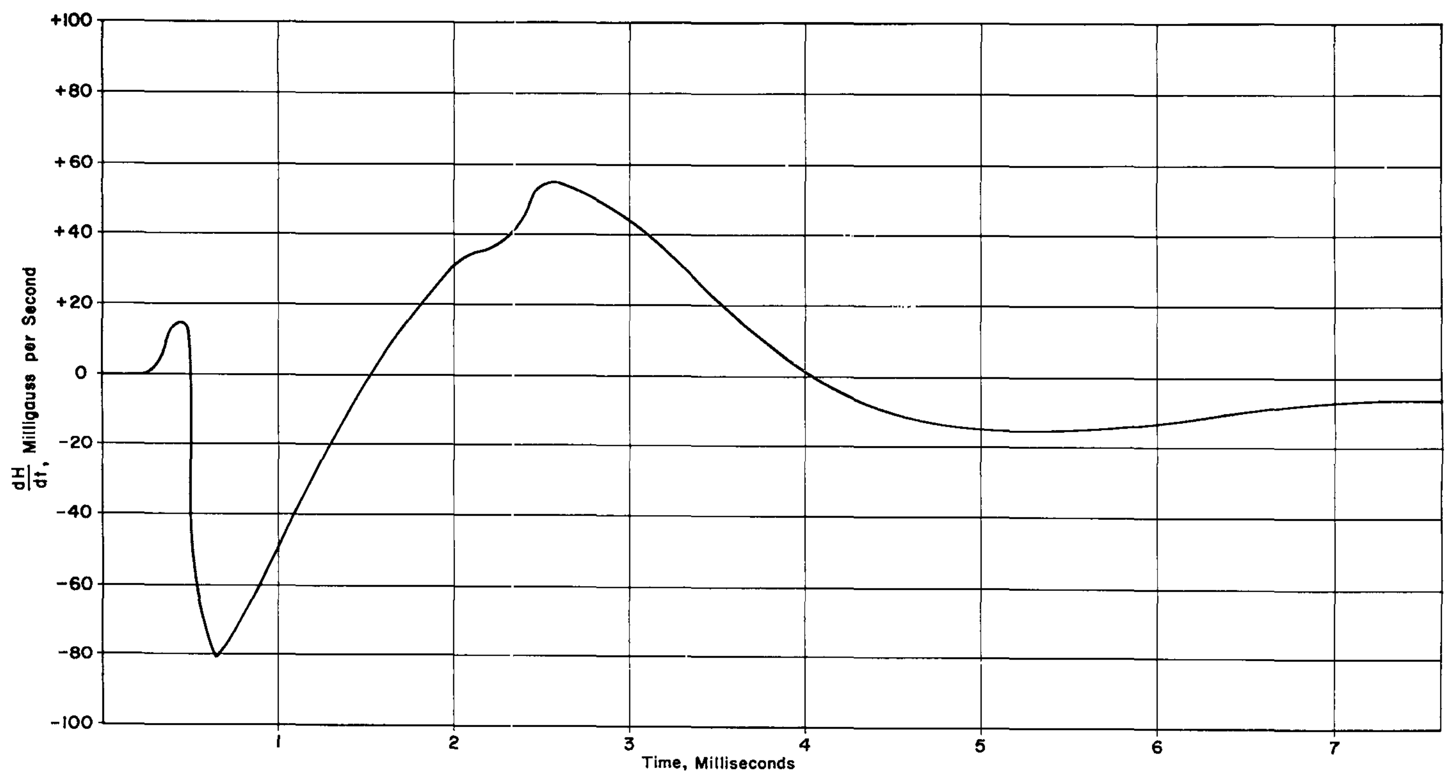


Figure 1. Time rate of change of magnetic field $\left(\frac{dH}{dt}\right)$ detected by horizontal loop antenna, 1,000 feet from detonation.

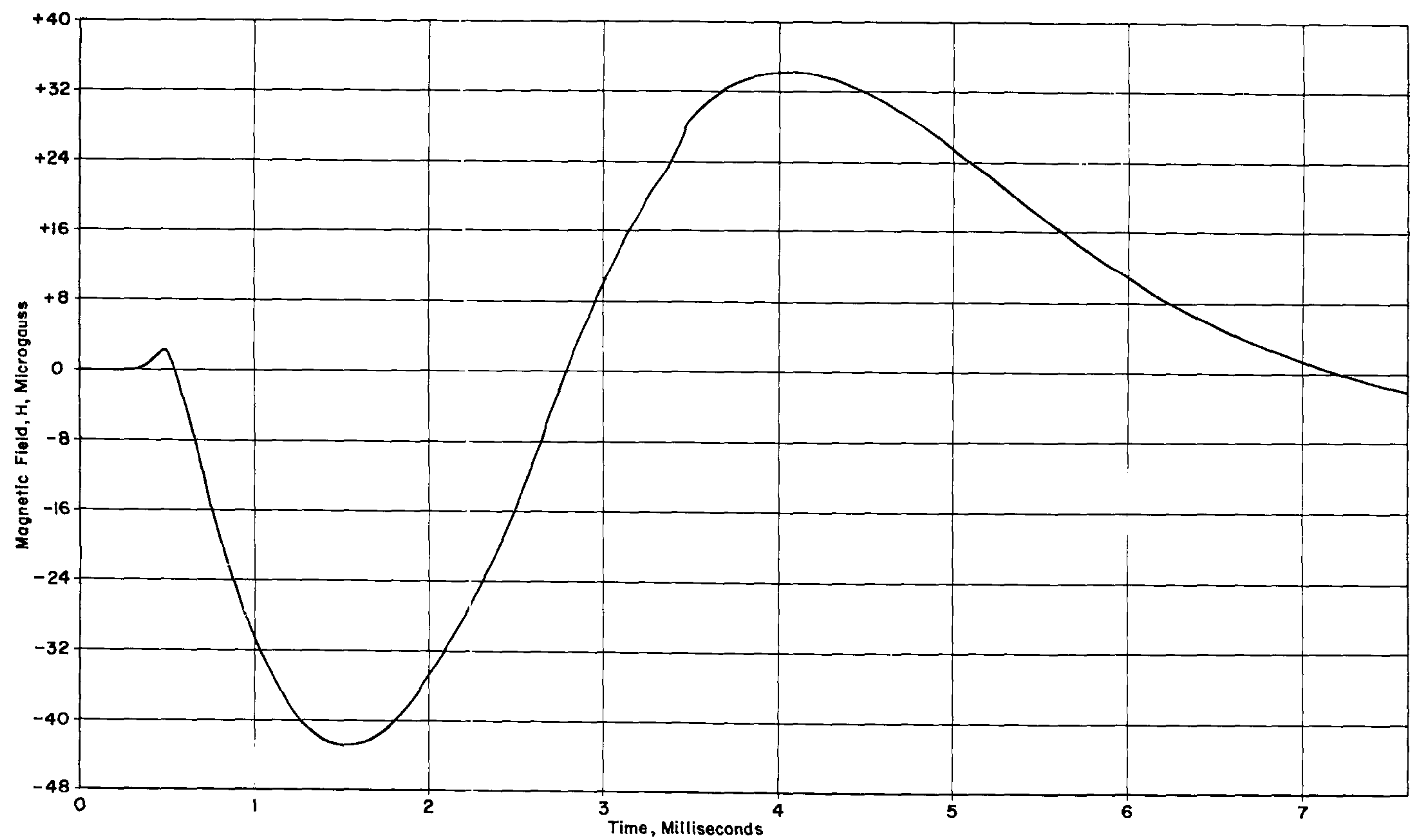


Figure 2. The magnetic field (H) detected by the horizontal loop antenna, 1,000 feet from detonation.

# CHAPTER 3

## RESULTS

There is some indication that the signal recorded on the horizontal loop located 1, 000 feet from the center of detonation may not be directly associated with the fireball. A second horizontal antenna, 1, 300 feet from the burst point, was located on the same approximate radius from the detonation center as the first antenna. The recording channel associated with this second antenna had the same sensitivity as did the recording channel for the near horizontal antenna. There was no signal on this more distant channel.

In the near field zone of a dipole, the field strength is inversely proportional to the cube of the distance. One would, therefore, expect the signal from the far horizontal antenna to be reduced by a factor of $\left(\frac{1300}{1000}\right)^3$ or 2. 2 compared with that from the near antenna. The fact that no signal was recorded from the second antenna raises the possibility that the signal received on the near antenna came from a source other than the detonation itself.

Owing to the presence of the Navy transmitter (NSS) at Annapolis, broadcasting at about 18 KC, an extremely high noise level was encountered on all of the vertical loops. As a consequence, it was necessary to reduce the sensitivity on these channels. Failure of the vertical loops, associated with both the near and the far antennas, to detect a component of the signal received by the near horizontal antenna could be the result of the difference in channel sensitivities.

The peak values of the measured magnetic field 1, 000 feet from the explosion are about 40 microgauss (see Figure 2). A simple expression giving the field strength at some distance from a magnetic bubble of given radius is

$$H_r = H_o\left(\frac{a}{r}\right)^3$$

where

| | |
|---|---|
| $H_r$ | is the magnetic field strength,at distance r |
| $H_o$ | is the strength of the earth's magnetic field, (about 0.5 Gauss) |
| r | is the distance from the source at which $H_r$ is measured. |

and

| | |
|---|---|
| a | is the radius of the magnetic bubble |

On the basis of the measured 40 microgauss field at a distance of 1,000 feet, it would appear that the effective radius "a" of the magnetic bubble is 43 feet. This 43-foot value for the effective radius of the conducting sphere is somewhat larger than one would expect from a 500 pound HE charge. Furthermore, the radius of this explosion measured by photographic means, was about 15 feet at 1.5 milliseconds, (D. F. Hansen and G. H. Hetley, Jr., "Streak Photography of Exploding 500 Pound Pentolite Charge", October, 1961, EG&G).

Considering free space EM measurement, an error factor of about 25 in the EM measurement would be required to explain the 3 to 1 ratio between the radius deduced from the EM data and that obtained photographically. The EM system was known to be calibrated to within ± 10% so that a 25:1 error in the measured value as a result of an error in system calibration is unlikely. On the other hand, if there were supplemental means for coupling the EM energy from the explosion to the antenna, in addition to the coupling predicted by free-space considerations, it would be possible to explain the enhanced EM signal on the basis of the improved coupling. This supplemental coupling could conceivably arise from buried pipes or cables running between the EM source and the pickup antenna.

One other feature of the observed EM signal which is difficult to explain by the magnetic bubble model is the polarity reversal of the magnetic field signal detected. Analysis indicates that the initial polarity of the local magnetic field at the pickup antenna is consistent with that which would be generated by the magnetic bubble mechanism. On the other hand, the second half-cycle of the magnetic field signal (see Figure 2) is of the opposite polarity. This polarity is inconsistent with the bubble model which provides only for a unidirectional expulsion of the local field and no polarity reversal in the magnetic field.

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# CHAPTER 4

# CONCLUSIONS

It is extremely difficult to draw any really significant conclusions on the basis of a single field measurement of this type. There are so many uncertainties regarding local conditions, the instrumentation and the like, that any further analysis of this data is probably quite pointless.

To summarize the tentative conclusions drawn from this one shot experiment: there was generated in the vicinity of the pickup antenna located 1,000 feet from the explosion, an EM field whose initial polarity and rise time were consistent with the magnetic bubble model, whose peak amplitude was 25 times greater than that predicted by the model, and whose polarity reversal on the second half-cycle was not consistent with the model.

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# APPENDIX A

## ELECTROMAGNETIC RECORDING SYSTEM

## XSY-30

The Electromagnetic Recording (EMR) System is designed to detect and record electromagnetic radiation. This radiation may be the product of any electromagnetic source, the origin of which is immaterial. The system is operated manually during system checkout and during playback. The system may operate, however, either manually or automatically during the recording process.

### DESCRIPTION

A. 1 General. The EMR system is composed of a Radio Tone Receiver, an Antenna Section, a Recording Rack, a Power Distribution Rack, and interconnecting cables. The major signal paths between the chassis are shown in a block diagram, Figure A. 1. Two separate commands are sent to the EMR system, either by conventional connecting wires or by radio signals, from a central timing and firing control system. The first signal received by the EMR system, five minutes before the event to be recorded, initiates a series of events in the EMR which prepares the system for the expected event. For some applications a zero time fiducial marker is also transmitted to the EMR system.

The antenna section receives the electromagnetic signals which are to be monitored and relays these signals to the recording rack. The signals are amplified and recorded on magnetic tape.

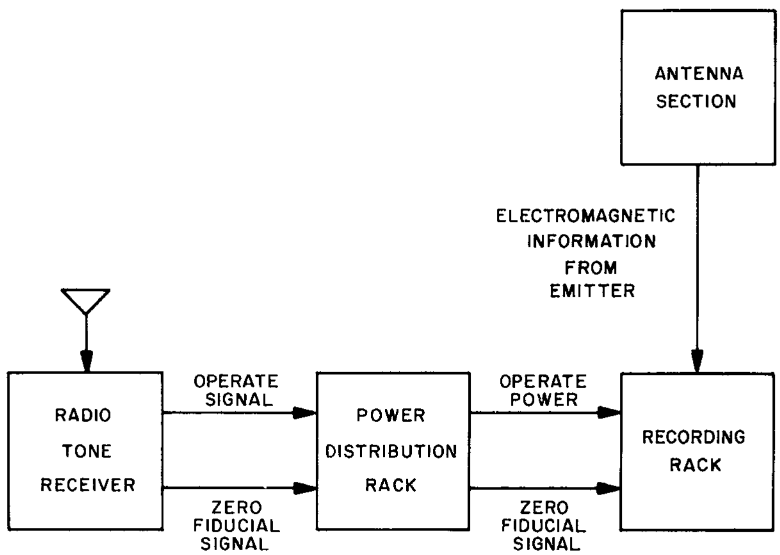



Figure A. 1 EMR system, block diagram

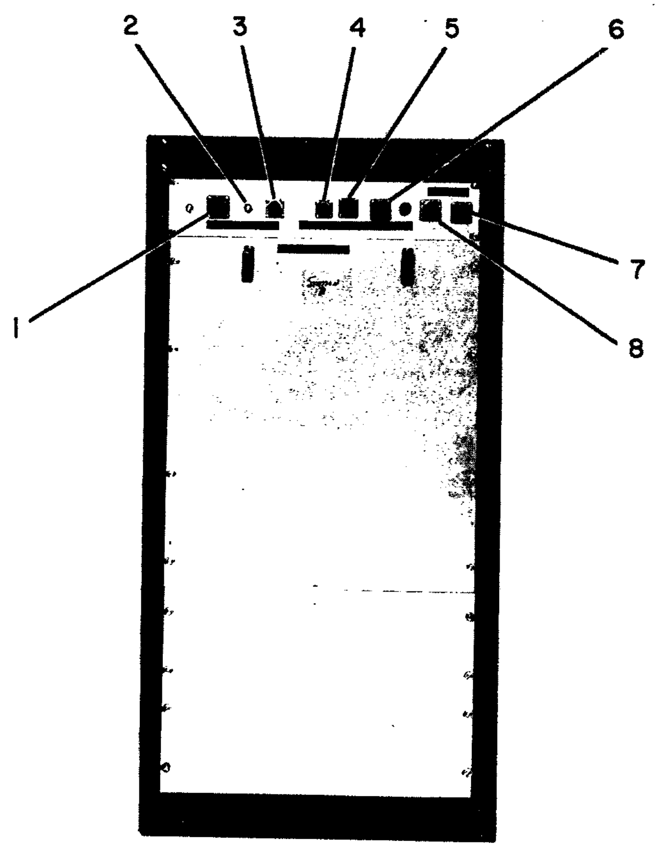
A. 2 Radio Tone Receiver. The Radio Tone Receiver, Model N3620-DI, is the component in the EMR system which receives the radio command signals. The first signal, the operate command, is relayed to the Power Distribution Rack. This signal actuates a programmer which controls the EMR system in a sequential manner. The second signal is the zero fiducial pulse which is relayed through the Power Distribution Rack to the Recording Rack.

A. 3 Power Distribution Rack. The Power Distribution Rack, Figure A. 2, contains a DC to 115 vac inverter, a 15-minute timer, and control circuits which perform the automatic operation of the system. The command signals from the Radio Tone Receiver are detected in the Power Distribution Rack which, in turn, energize various circuits in the system. The duration and programming of the system operation is controlled by a cam timer.

A. 4 Antenna Section. The Antenna Section, Figure A. 3, consists of three loop antennas with their preamplifiers and associated cabling. Each loop antenna is 30 inches in diameter and contains 11 turns of wire within an electrostatic shield. The three antennas are arranged so that their axes are mutually perpendicular. The received electromagnetic energy is resolved into three orthogonal components.

The three preamplifiers and the power connectors were not mounted on the antenna bracket as shown in Figure A. 3 but were placed approximately 25 feet from the antennas. Each preamplifier amplifies the signal from the antenna to which it is connected and then passes the signal through the signal cables to the recording system.

A. 5 Recording Rack. The Recording Rack, Figure A. 4, is composed of a four-track magnetic tape recorder, a distribution panel, a monitor panel, two dual-channel amplifiers, and a power supply chassis mounted on a relay rack. The signals received from the Antenna Section are again amplified and recorded on three separate tracks (channels). Track 4 carries a CW timing wave and a zero time reference signal. The zero fiducial mark is obtained from a type TD-2A Photoelectric Fiducial Marker.




1. -5 MIN. connector
2. INV. TEST switch
3. FIDU connector
4. INV. REMOTE connector
5. TAPE RECORDER connector
6. 115 vac INV. connector
7. 115 VOLTS LINE output connector
8. 115 VOLTS LINE input connector

Figure A. 2 Power distribution rack

The amplitude of the signal level in each channel can be adjusted by the controls on the recorder amplifiers to ensure that each signal is amplified to the correct recording level. The signal in any channel may be visually monitored by connecting an oscilloscope to the channel output.

The power supply, contained in the bottom section of the Recording Rack, provides power for the CW timing oscillator and the three preamplifiers in the Antenna Section.

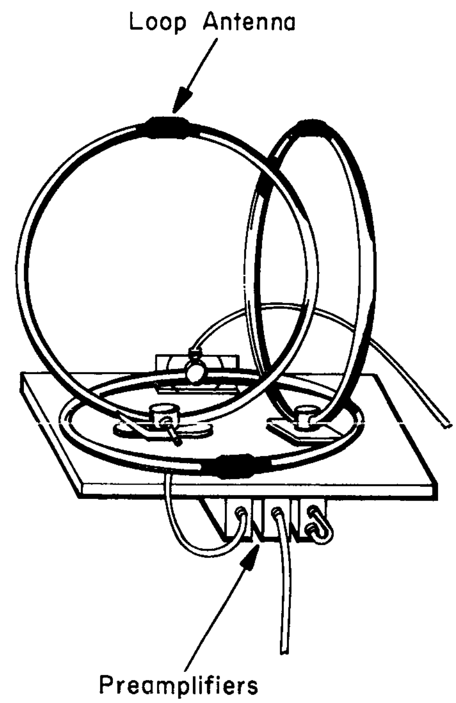
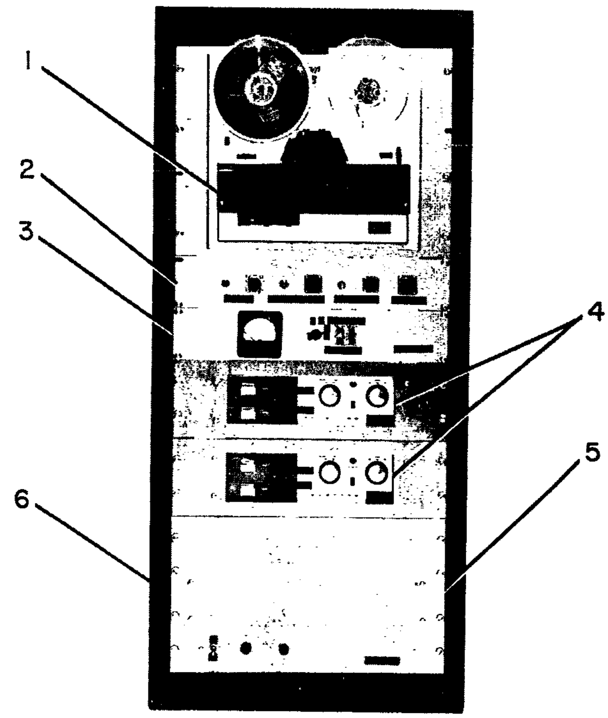



Figure A. 3 Antenna section




1. Magnetic tape recorder
2. Distribution panel
3. Monitor panel
4. Dual-channel amplifiers
5. Power supply
6. Relay rack

Figure A.4 Recording rack

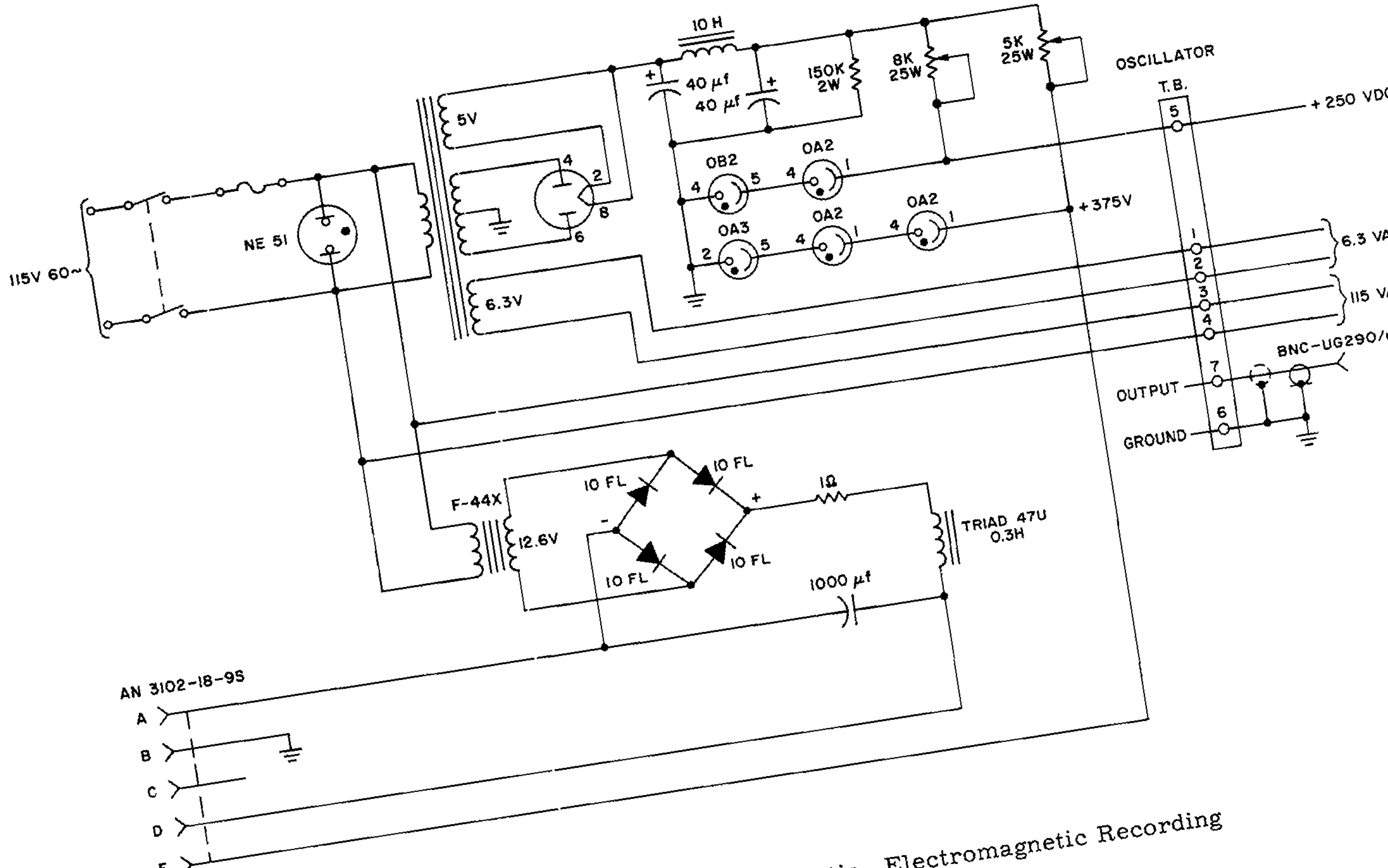



Figure A. 5 Power supply schematic, Electromagnetic Recording System XSY-30.

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NOTE:
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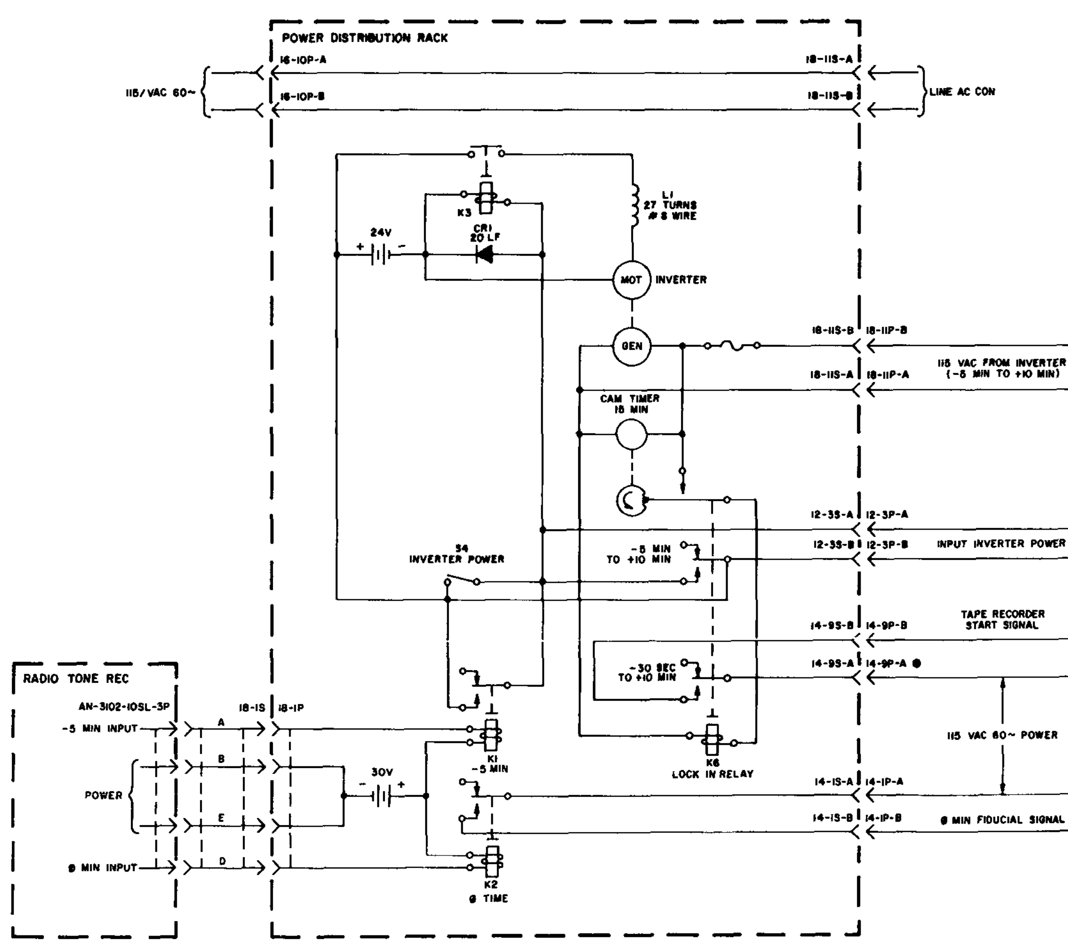


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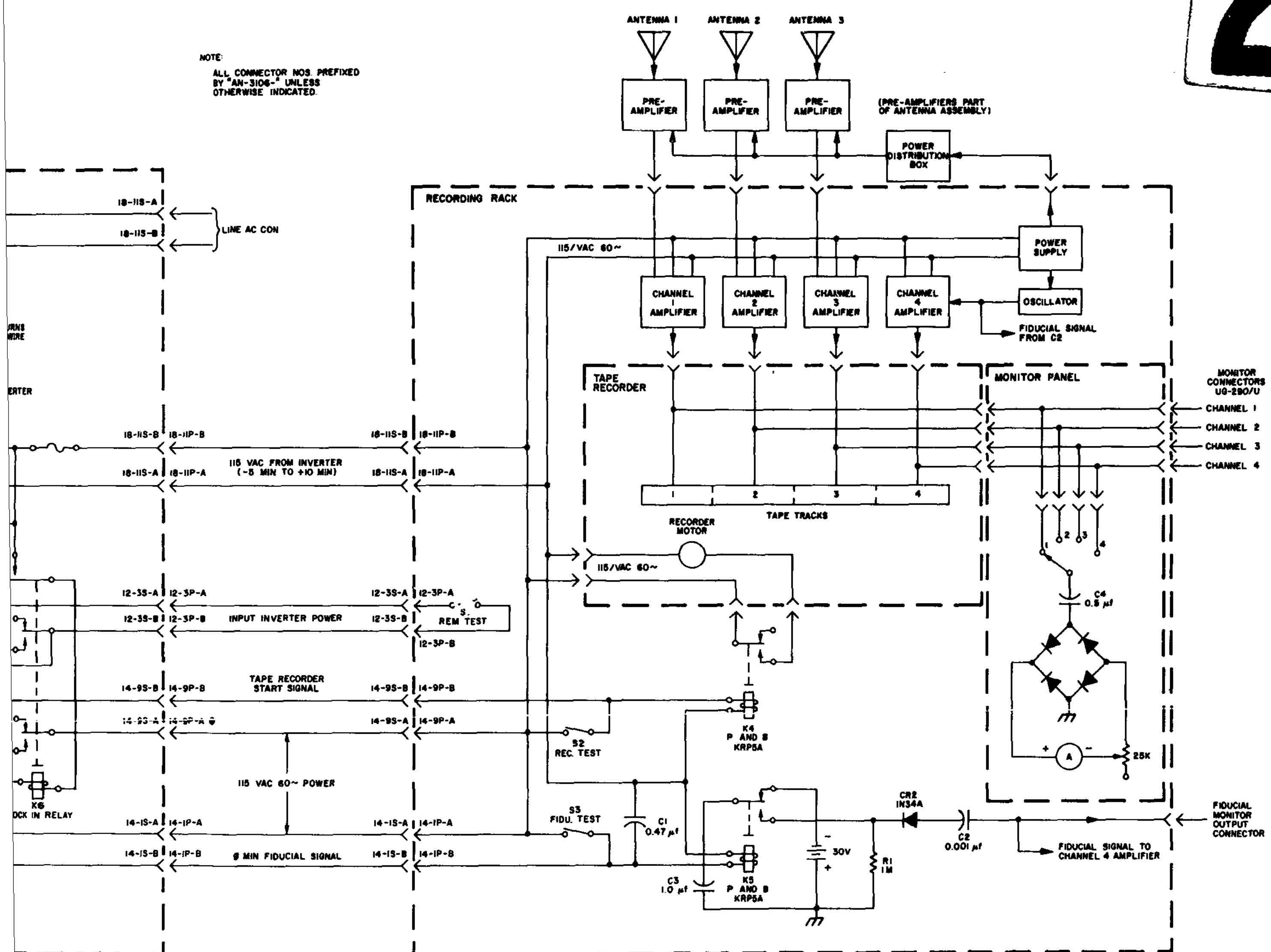


Figure A. 6 Functional diagram, Electromagnetic Recording System.

# APPENDIX B

## FIDUCIAL MARKER

## TD-2A

The Type TD-2A Fiducial Marker is a photoelectric device which can be used to synchronize other equipment with the beginning of a fast-rising light pulse. Four parallel-connected outputs are provided. The output is a sharp pulse with a rise time of 0.05 microseconds, a duration of 2 to 12 microseconds when terminated in resistances of from 9 to 50 ohms, and a peak amplitude of 400 volts.

If an impedance of 25 ohms or less is connected to the output of the Fiducial Marker, the marker will reset itself. When using a greater impedance, the Fiducial Marker must be reset manually by pressing the reset button momentarily. A neon lamp indicates when the unit has been triggered.

The Type TD-2A Fiducial Marker is equipped with a 6-power telescope which serves two purposes; to allow the Marker to be directed towards a source of the light pulse, and to divert 50 percent of the intensity of the light pulse to the photocell. The telescope has an adjustable field of view with a maximum total field angle of $7.1^{\circ}$.

The circuit diagram of the unit is shown as Figure B. 1.

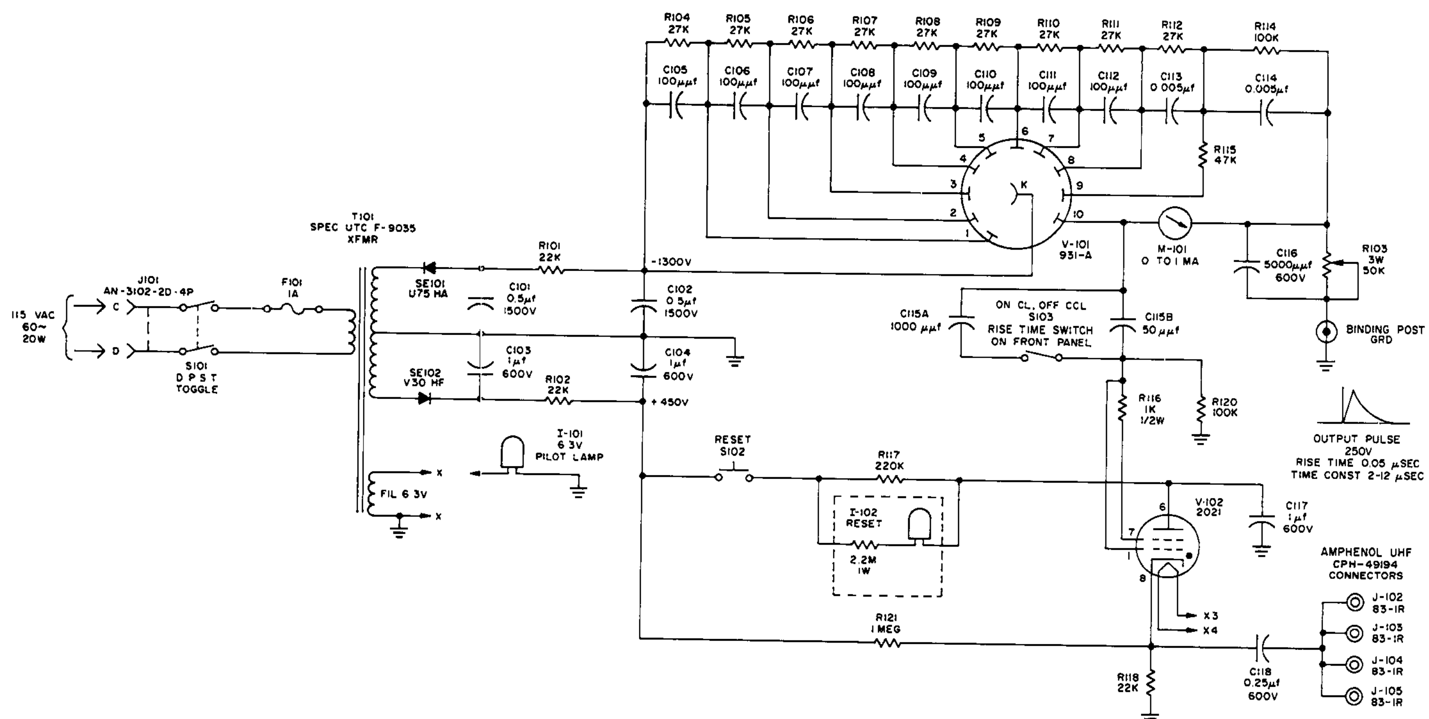


Figure B. 1 Circuit diagram, Fiducial Marker TD-2A.

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